Methodology

AIRS Methodology

The ambient air quality data presented in Chapters 2 and 3 of this report are based on data retrieved from AIRS on July 20, 2000. These are direct measurements of pollutant concentrations at monitoring stations operated by state and local governments throughout the nation. The monitoring stations are generally located in larger urban areas. EPA and other federal agencies also operate some air quality monitoring sites on a temporary basis as a part of air pollution research studies. The national monitoring network conforms to uniform criteria for monitor siting, instrumentation, and quality assurance.[1,2]

Emission estimation methods used for historical years prior to 1985 are considered "top-down approaches," e.g., pollutant emissions were estimated by using national average emission characterization techniques (for NO_x, VOC, CO, Pb, and PM_{10}). Emission estimates for the years 1985–present represent an evolution in methods for significant categories resulting in a "bottom-up approach" including data submitted directly by state/local agencies (for all criteria pollutants, $PM_{2.5}$ and NH_3).

In 1999, 4,184 monitoring sites reported air quality data for one or more of the six NAAQS pollutants to AIRS, as seen in Table B-1. The geographic locations of these monitoring sites are displayed in Figures B-1 to B-6. The sites are identified as National Air Monitoring Stations

Table B-1. Number of Ambient Monitors Reporting Data to AIRS

Pollutant	# of Sites Reporting Data to AIRS in 1999	# of Trend Sites 1990–1999
CO	531	388
Pb	265	175
NO_2	424	230
O_3	1,086	703
PM_{10}	1,214	954
SO_2	637	480
Total	4,184	2,930

(NAMS), State and Local Air Monitoring Stations (SLAMS), or "other." NAMS were established to ensure a long-term national network for urban area-oriented ambient monitoring and to provide a systematic, consistent data base for air quality comparisons and trends analysis. SLAMS allow state or local governments to develop networks tailored for their immediate monitoring needs. "Other" monitors may be Special Purpose Monitors, industrial monitors, tribal monitors, etc.

Air quality monitoring sites are selected as national trends sites if they have complete data for at least eight of the 10 years between 1990 and 1999. The annual data completeness criteria are specific to each pollutant and measurement methodology. Table B-1 displays the number of sites meeting the 10-year trend completeness criteria. Because of the annual turnover of monitoring sites, the use of a moving 10-year window maximizes the number of sites available for trends and yields a data base that is consistent with the current monitoring network.

The air quality data are divided into two major groupings: daily (24-hour) measurements and continuous (1-hour) measurements. The daily measurements are obtained from monitoring instruments that produce one measurement per 24-hour period and typically operate on a systematic sampling schedule of once every six days, or 61 samples per year. Such instruments are used to measure PM_{10} and lead. More frequent sampling of PM_{10} (every other day or every day) also is common. Only PM_{10} weighted (for each quarter to account for seasonality) annual arithmetic means that meet the AIRS annual summary criteria are selected as valid means for trends purposes.[3] Beginning in 1998, some sites began reporting PM_{10} data based on local conditions, instead of

Figure B-1. Carbon monoxide monitoring network, 1999.

- • NAMS
- ○ SLAMS
- + Other

Figure B-2. Lead monitoring network, 1999.

- • NAMS
- ○ SLAMS
- + Other

Figure B-3. Nitrogen dioxide monitoring network, 1999.

- • NAMS
- ○ SLAMS
- + Other

Figure B-4. Ozone monitoring network, 1999.

- • NAMS
- ○ SLAMS
- + Other

Figure B-5. PM_{10} monitoring network, 1999.
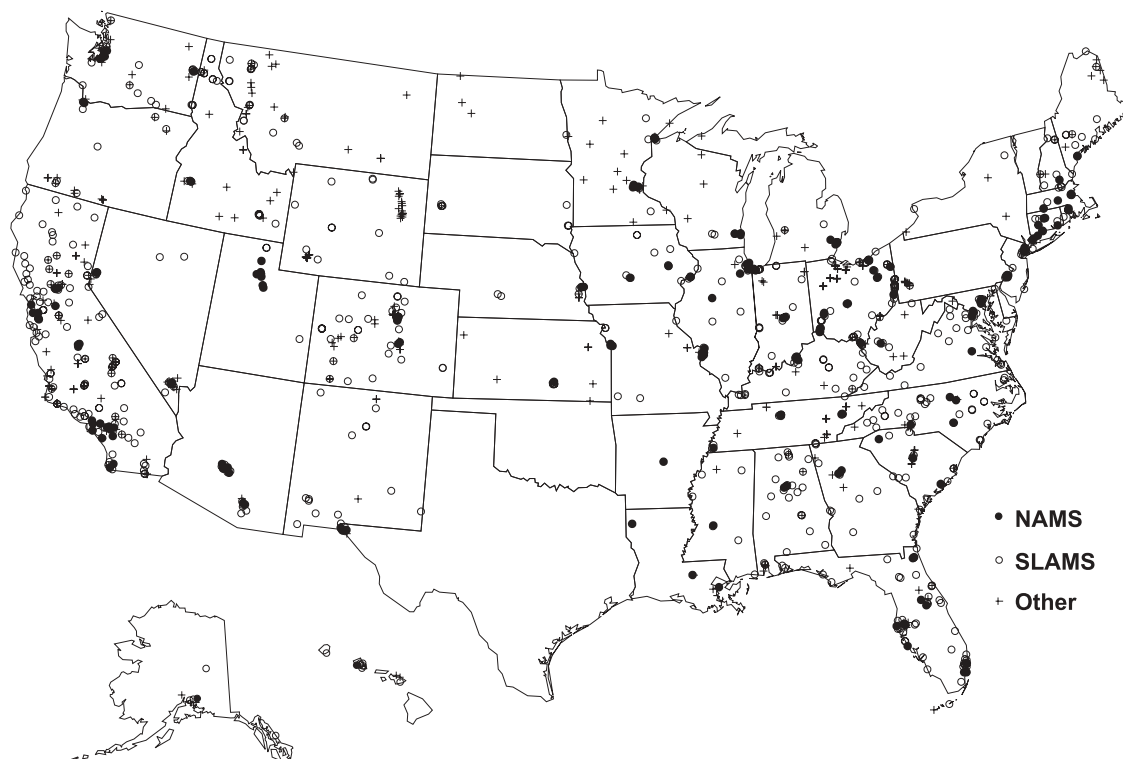

Figure B-6. Sulfur dioxide monitoring network, 1999.

standard, or "reference," conditions. For these sites, PM_{10} statistics were converted from local conditions to standard conditions to ensure all PM_{10} data in this report are consistent and reflect standard conditions.[4] Only lead sites with at least six samples per quarter in three of the four calendar quarters qualify as trends sites. Monthly composite lead data are used if at least two monthly samples are available for at least three of the four calendar quarters.

Monitoring instruments that operate continuously produce a measurement every hour for a possible total of 8,760 hourly measurements in a year. For hourly data, only annual averages based on at least 4,380 hourly observations are considered as trends statistics. The SO_2 standard-related daily statistics require at least 183 daily values to be included in the analysis. Ozone sites meet the annual trends data completeness requirement if they have at least 50 percent of the daily data available for the ozone season, which varies by state, but typically runs from May through September.[5]

Air Quality Trend Statistics
The air quality statistics presented in this report relate to the pollutant-specific NAAQS and comply with the recommendations of the Intra-Agency Task Force on Air Quality Indicators.[6] A composite average of each trend statistic is used in the graphical presentations throughout this report. All sites were weighted equally in calculating the composite average trend statistic. Missing annual summary statistics for the second through ninth years for a site are estimated by linear interpolation from the surrounding years. Missing end points

are replaced with the nearest valid year of data. The resulting data sets are statistically balanced, allowing simple statistical procedures and graphics to be easily applied. This procedure is conservative since end-point rates of change are dampened by the interpolated estimates.

Emissions Estimates Methodology

Trends are presented for annual nationwide emissions of CO, lead, NO_x, VOC, PM_{10}, and SO_2. These trends are estimates of the amount and kinds of pollution being emitted by automobiles, factories, and other sources based upon best available engineering calculations. Because of recent changes in the methodology used to obtain these emissions estimates the estimates have been recomputed for each year. Thus, comparisons of the estimates for a given year in this report to the same year in previous reports may not be appropriate.

The emissions estimates presented in this report reflect several major changes in methodologies that were instituted mainly in 1996. First, state-derived emissions estimates were included primarily for nonutility point and area sources. Also, 1985–1994 NO_x emission rates derived from test data from the Acid Rain Division, U.S. EPA, were utilized. The MOBILE5b model was run instead of MOBILE5a for the years 1995 through 1999. For 1985–1999, the Office of Transportation and Air Quality, U.S. EPA, provided new estimates from the beta version of the nonroad model for most nonroad diesel and gasoline equipment categories. Finally, additional improve-

ments were made to the particulate matter fugitive dust categories.

In addition to the changes in methodology affecting most source categories and pollutants, other changes were made to the emissions for specific pollutants, source categories, and/or individual sources. Activity data and correction parameters for agricultural crops and paved roads were included. A change in methodology occurred starting in 1996 for calculating PM_{10} emissions from unpaved roads and in 1999 for calculating emissions from construction. This has led to lower PM_{10} emissions than would have been predicted using the previous methods. The development of new emission estimation methodologies have added emissions for open burning of residential yard waste and land-clearing debris burning. Starting in 1999, these estimates contributed to a significant increase in industrial category emissions for CO, PM_{10} and $PM_{2.5}$ between 1998 and 1999. State-supplied MOBILE model inputs for 1990, 1995, and 1996 were used, as well as state-supplied VMT data for 1990. In addition, there were VMT methodology changes starting in 1995 that affected the allocation of state or metropolitan area VMT to counties. Rule effectiveness from pre-1990 chemical and allied product emissions was removed. Lead content of unleaded and leaded gasoline for the onroad and nonroad engine lead emission estimates was revised, and Alaska and Hawaii nonutility point and area source emissions from several sources were added. Also, this report incorporates data from CEMs collected between 1994 and 1999 for NO_x and SO_2 emissions at major electric utilities.

All of these changes are part of a broad effort to update and improve emissions estimates. Additional emissions estimates and a more detailed description of the estimation methodology are available from EPA's Emission Factor and Inventory Group.

IMPROVE Methodology

Data collected from the Interagency Monitoring of Protected Visual Environments (IMPROVE) network is summarized in Chapters 2 ($PM_{2.5}$ section) and 6 of this report. The completeness criteria and averaging method used to summarize the IMPROVE data are slightly different from those used for the criteria pollutants. (Data handling guidance is currently being developed for the IMPROVE network. Future summaries will be based on this guidance.) The source data sets were obtained from Dr. James Sisler of Colorado State University.

The annual average statistics in these files were used to assess trends in this report. The IMPROVE data are not reported in terms of a calendar year. The IMPROVE year runs from March to February of the following year. It follows that the four seasons are: March to May (spring), June to August (summer), September to November (autumn), and December to the following February (winter). The network samplers monitor on Wednesdays and Saturdays throughout the year, yielding 104 samples per year and 26 samples per season. To be included in this analysis, sites were required to have data at least 50 percent of the scheduled samples (13 days) for every calendar quarter.

IMPROVE monitoring sites are selected as trends sites if they have complete data for at least eight of the

Figure B-7. Class I Areas in the IMPROVE Network meeting data completeness criteria.

10 years between 1990 and 1999 or (six of eight years for those who began monitoring in 1992). A year is valid only if there are at least 13 samples (50 percent complete) per season for both measured and reconstructed $PM_{2.5}$. The same linear interpolation applied to the criteria pollutants is applied here. The IMPROVE sites meeting the data completeness criteria are shown in Figure B-7.

For consistency, the same sites are used in both the $PM_{2.5}$ section and the Visibility chapter. The exceptions are Washington D.C. and South Lake Tahoe, which are not included in the visibility trends analysis because they are urban sites.

Air Toxics Methodology

Database
The 1990–1999 ambient air quality data presented in Chapter 5 of this report are based on air toxics data retrieved from AIRS in July, 2000, data retrieved from the IMPROVE network <**ftp:// alta_vista.cira.colostate.edu/DATA/ IMPROVE/>** in June, 2000, and data voluntarily submitted to EPA by state and local monitoring agencies and received by June 30, 2000. For more details about the database, see Rosenbaum *et al*, 1999.[7] All statistical summaries are based on annual average concentrations. Measurements for hazardous air pollutants (HAPs) are frequently reported as non-detectable concentrations. To calculate annual average concentrations, one-half of the actual or plausible detection limit is used to substitute values for nondetects (or if the reported value is zero). The plausible detection limit, used for cases where the MDL is missing, is the lowest of the measured concentrations and MDLs for the given monitor and HAP.

Separate summaries are presented for sites in an MSA/PMSA, excluding the (primarily rural) sites from the IMPROVE network, and for other sites. Areas (one or more counties) are either assigned to a MSA, to a CMSA (consolidated MSA) consisting of two or more PMSAs (primary MSAs), or are just assigned to a county. Each non-IMPROVE site in an MSA or CMSA was assigned either to its MSA or PMSA. Some analyses allocated MSA/PMSAs to states. If the MSA/PMSA crosses state boundaries, the state containing the largest portion of that MSA/PMSA was used.

Completeness
All calculations are based on the average of calculated or measured 24-hour values. For each HAP, a series of completeness rules are applied sequentially starting with using the raw hourly data to determine daily completeness. Multiple records for the same HAP, monitoring site, day, and time period are averaged together. A day is complete if the total number of hours monitored for that day is 18 or more (i.e., 75 percent of 24 hours). For example, 18 hourly averages, three 6-hour averages, or three 8-hour averages will satisfy the daily completeness criteria. Once daily completeness is satisfied, quarterly completeness is determined. Calendar quarters are 1. (Late winter) January–March, 2. (Early summer) April–June, 3. (Late summer) July–September, 4. (Early winter) October–December. A calendar quarter is complete if it has 75 percent or more complete days out of the expected number of daily samples for that quarter, and if there are at least five complete days in the quarter. To determine the expected number of daily samples, the most frequently occur-

ring sampling interval (days from one sample to the next sample) was used; in cases of ties, the minimum sampling interval was applied. A calendar year is complete if both the summer and winter six month seasons have at least one complete quarter, i.e., if a) quarter 1 or quarter 4 or both quarters 1 and 4 are complete, and b) quarter 2 or quarter 3 or both quarters 2 and 3 are complete.

In some cases, co-located samples for the same HAP and location were collected. For AIRS data, co-located monitors are identified by having the same 9-digit AIRS ID number but a different POC number. The higher POC numbers are generally used for quality assurance monitoring data that are not as complete as the primary sampling data. Therefore, if multiple AIRS monitors at the same location meet the above completeness requirements, then only the data from the monitor with the lowest POC number was used for these analyses. For data not reported to AIRS, co-located monitors can have very different monitor identifiers. If multiple monitors at the same latitude and longitude location for a given sampling program and HAP meet the completeness requirements, then only the data from the monitor with the highest monitoring frequency was used for these analyses. In case of tied highest monitoring frequencies, the monitor with the most daily average records (from complete quarters in the trend period) was used.

National Analyses
Based on the available years of monitoring data across the nation, the national analyses were restricted to the six-year period 1994–1999. A site

was included for a particular HAP if, and only if, there were four or more complete years for that period.

California Analyses
A similar, but longer term trend analysis was performed on metropolitan sites located only in California using 1990–1999 data. A site was included for a given HAP if there was at least one period of five years or longer such that a) at least 75 percent of those years are complete, and b) the period ends in 1997 or later. Only the data from the most recent of the longest such periods was used.

Trend Analysis
Annual averages for years with four complete quarters were computed by averaging the four quarterly averages. If a year had one or more missing or incomplete quarters, then those missing or incomplete quarterly averages were filled in (if possible) using the General Linear Model (GLM) fill-in methodology described below and the annual average was computed by first averaging the quarterly averages (actual or filled-in) for a season and then averaging across the two seasons.[8] Filled-in quarterly averages were used for incomplete quarters even if there was some data for that quarter. Data from incomplete quarters was not used in the analyses. Sometimes, the filled in quarterly average can be negative and occasionally this leads to a negative annual average. To deal with this case, negative or zero filled-in quarterly averages were used to compute the annual average (this avoids biasing the results), but any resulting negative annual averages were reset to zero. In the summary analyses, averages across multiple sites were computed as trimmed means rather than

simple arithmetic means in order to reduce the influence of the most extreme monitor averages on the trend line. If there were nine sites or less, then no trimming was performed, so the trimmed mean is the arithmetic mean of all the site averages. If there were between 10 and 40 sites, inclusive, the trimmed mean is the arithmetic mean of all the site averages except for the highest and lowest averages. If there were 41 sites or more, the trimmed mean is the arithmetic mean of all the site averages except for the highest 2.5 percent and the lowest 2.5 percent of the averages. The reported numbers of sites and percentiles are based on all sites meeting the completeness criteria, i.e., including the sites that were excluded for the trimmed mean calculation.

The overall slope (trend) was estimated non-parametrically as the median of the ratios of the difference in the annual average to the difference in calendar year, for all pairs of calendar years. The significance level of the trend was computed using the associated non-parametric Theil test, based on the number of pairs of years where the annual averages increased. The p-values are calculated for a two-sided test for whether or not the annual averages have a trend (which may be increasing or decreasing). The trend is reported as "Significant Up Trend" or "Significant Down Trend" if the corresponding one-sided test is significant at the five percent significance level; otherwise the result is reported as "Non-significant Up Trend," "no trend," or "Non-significant Down Trend."

For the tables summarizing the annual average trends by monitor, the GLM fill-in method was not used. Instead, those monitor annual aver-

ages were computed by averaging all complete daily averages for each complete quarter, then averaging the complete quarterly averages for each season, and then, finally, averaging over the two seasons. All other analyses used the filled-in quarterly averages as described above.

GLM Fill-in Methodology

The general linear model (GLM) fill-in methodology and software used to fill in missing quarterly averages was based on the report by Cohen and Pollack (1990),[9] which can be consulted for more details. The method was modified to apply to the sequence of quarterly averages (24 values for the six year 1994–1999 period) instead of five annual means. The method was also modified to use a fitted statistical model with six year effects and four quarterly adjustments, instead of having 24 independent year/quarter effects. In other words, the fitted model assumes that the seasonal (quarterly) variation is the same for every site and year. Initially, each site is allocated to a region, which for these analyses was the MSA/PMSA for sites within an MSA or PMSA, or else was the county. Suppose that for each of the four quarters there is at least one site in the region with complete data for that quarter in at least one year. Suppose also that for each of the six years there is at least one site in the region with complete data for at least one quarter in that year. If these two conditions apply, then the missing quarterly averages for all sites in that region are computed by fitting a general linear model such that the expected value for a given site and quarter q is the sum of the site average, a yearly adjustment term, and a quarterly adjustment term. The year-

ly adjustment term is the fixed effect of the y'th year, $1 <= y <= 6$, assumed to be the same value for all sites in the region. The quarterly adjustment term is the fixed effect of the q'th quarter, $1 <= q <= 4$, assumed to be the same value for all sites in the region and all years. If a region does not meet these two conditions, then the region is expanded to become a larger, augmented region with some site data for every quarter, and some site data for every year, and the GLM approach is applied to the augmented region. Candidates for the augmented region are selected by finding the nearest site(s) in the same state that have complete data for the missing quarter(s) and year(s). The selected augmented region is the region giving the lowest mean square error for the GLM model.

Although the GLM methodology filled in most missing quarters, there were some states, HAPs and years that had no complete quarters for any site in the state, and in those cases the missing quarters were not filled in by the GLM approach (which restricts the augmented regions to sites in the same state). For the national analyses of distributions across sites in different states, the missing site-years were then filled in using the same EPA extrapolation and interpolation method used elsewhere in the Trends report: If the site annual average for 1994 was missing, it was filled in with the 1995 annual average; if the 1995 annual average was also missing, then the 1994 and 1995 annual averages were filled in with the 1996 annual average. If the site annual average for 1999 was missing, it was filled in with the 1998 annual average; if the 1998 annual average was also missing, then the 1999 and 1998 annual averages were filled in with

the 1997 annual average. Otherwise, any missing annual averages were filled in using simple linear interpolation from the two surrounding annual averages.

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2.   Ambient Air Quality Surveillance, 44 CFR 27558, May 10, 1979.

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5.   Ambient Air Quality Surveillance, 51 FR 9597, March 19, 1986.

6.   U.S. Environmental Protection Agency Intra-Agency Task Force Report on Air Quality Indicators, EPA-450/4-81-015, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC, February 1981.

7.   Rosenbaum, A. S., Stiefer, M. P., and Iwamiya, R. K. November, 1999. *Air Toxics Data Archive and AIRS Combined Dataset: Contents Summary Report.* SYSAPP-99/26d. Systems Applications International, San Rafael, CA.

8.   In all cases analyzed, four nonmissing quarterly means were available after applying the GLM method, so that the resulting annual mean is the arithmetic mean of the four quarterly averages.

9.   Cohen, J.P. and A. K. Pollack. 1990. *General Linear Models Approach to Estimating National Air Quality Trends Assuming Different Regional Trends.* SYSAPP-90/102. Systems Applications International, San Rafael, CA.